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Study on the affect of aspect building form and layout case study: Honjo Nishi Danchi, Yahatanishi, Kitakyushu - Fukuoka

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Abstract

The urban layout, from the form and placement of the building complex, configures open space and creates a distinct microclimate. This paper, then, tried to compare two building groups which have different building layouts (size, shape and orientation) in the same neighborhood to seek site microclimate. The numerical model of ENVI-met was used with specific temperature, humidity and wind speed; that would simulate the microclimatic change within urban environment. This model was practiced on the hottest day in summer at 7th August in Kitakyushu (33°50'N; 130°50'E), a region characterized by warm and humid temperatures in hot summers and no dry season. A description of microclimate with different orientation would be the emphasis and it was placed during the daylight into the building. The results showed a pattern of mean radiant temperature (MRT) correlated with building layout and its configuration created open space. A comparison of building group revealed that time and period during the day when extreme heat stress occurred provide a better building configuration.

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Keywords: building form and layout, MRT, ENVI-met

1. Introduction

Many studies on urban geometry associated with the microclimate have been done and there are fairly significant relationships between the ratio of height (H) of building and distances/wide (W) between them which influence both incoming and outgoing radiation and wind speeds; they become two main parameters of urban geometry and thermal properties of urban surfaces Oke [1],[2],[3]. This study is

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focusing on building form and layout which are height to width ratios or orientation of urban structure; these physical aspects influence mean radiant temperature and wind speed and correspond to three levels of thermal stress. The mean radiant temperature (T_{mrt}) is the most important meteorological input parameter for the human energy balance during sunny weather in summer. T_{mrt} is defined as “the uniform temperature of a surrounding surface giving of blackbody radiation (emission coefficient $\epsilon = 1$) which results in the same radiation energy gain of a human body as the prevailing radiation fluxes which are usually very varied under open space conditions.” T_{mrt} can be either obtained by direct measurement of all relevant radiation fluxes or by calculations of the short-wave and long-wave radiation fluxes [4].

2. Study Area

Danchi (団地 Lit . group land) is the Japanese word for a large cluster of public housing, typically built by government authority. The Japan Housing Corporation (JHC), now known as the Urban Renaissance Agency (UR), was founded in 1955. During the 1950s, 60s and 70s, the JHC built many Danchi in suburban areas to offset the housing demand of the then-increasing Japanese population. As a cluster settlement, Danchi consists of building group and set within the layout by street geometry, which has an important effect on the urban climate, modifying the ground surface temperature as well as the temperature of the air directly above it. Danchi is one of the affordable houses with single loaded design and typically built by particular module of width x length x height = 10x55x25m (with five floors) and 11x45x50m (with ten floors). This house was not equipped with air conditioning as the utility of mechanical thermal comfort in the room; consequently, the outdoor microclimate significantly influences the indoor thermal comfort. Honjo Nishi Danchi is chosen as the study area which is located in Kitakyushu city (33°50'N; 130°50'E), Yahatanishi ward; this ward is the densest area in Kitakyushu. This study is focused on two building groups with different shapes and orientations are taken to compare urban forms which influence the outdoor microclimate. (fig.1)

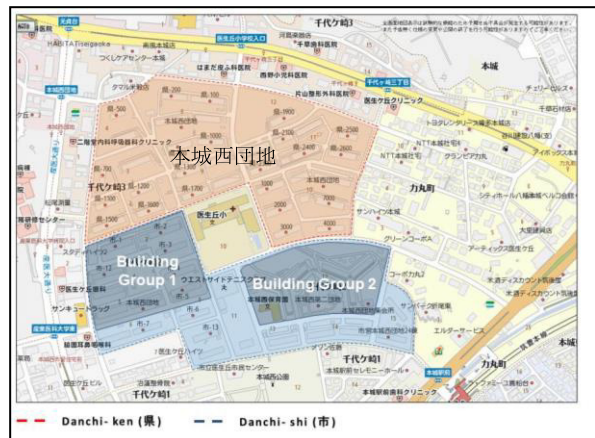


Fig. 1. Site of case studies of building group 1 and 2

3. Method

3.1. Microclimate Simulation

The difference of building forms and layouts, particularly the ratio of H/W, will influence mean radiant temperature. ENVI-met is used to calculate the microclimate and air quality in urban structure and open space which its physical fundamentals are based on the principles of fluid mechanics (wind field), thermodynamics (calculation of temperature) and the laws of atmospheric physics (e.g. prognosis of turbulence) and taken during the hottest day in summer [5]. A comparison of T_{mrt} building group reveals that time and period of the day during which extreme heat stress occurred on August 7th provide a better building configuration. A number of simulations are using ENVI-met BETA5; it appeared to be a good tool for the prognosis of the urban microclimate changes within urban areas and also in the

assessment of outdoor comfort through a satisfactory estimation of the mean radiant temperature [3]. In most cases, the options for optimizing the urban environment with respect to local climate are limited because the general city structures cannot be changed. What remain as the options for improvement are small changes within the given structures. To simulate the effects of these small-scale changes, there is a need for high-resolution models, which can accurately represent the properties, and the interactions between different urban elements, such as, building walls and roofs, paved surfaces, natural soils or vegetation in different sizes and types [5].

3.2. Meteorology Data

Kitakyushu which is within 40 km of this station is covered by *oceans and seas* (41%), *forests* (33%), *shrublands* (15%), *croplands* (6%) and *built-up areas* (3%). The *warm season* lasts from June 24th to September 21th with a daily average of high temperature above 26°C. The hottest day of the year is August 7th, with an average of high temperature of 30°C and low temperature of 26°C, with sunrise at 5.30am and sunset at 7.12pm; therefore, this simulation was conducted on August 7th between 6am – 7pm (13hours)

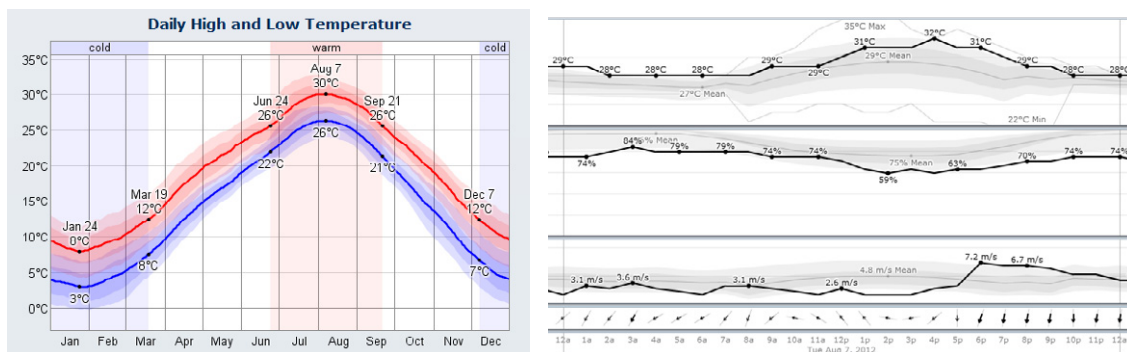


Fig. 2. (a) Daily High and Low Temperature for 1year (www.weatherspark.com); (b) Measurement on August 7th, 2012 (<http://www.jma.go.jp/jma/menu/report.html>)

3.3. Site selection



Fig. 3. (a) Building Group 1 (G1) ; (b) Building Group 2 (G2)

Table 1. General condition for the simulations

Location	Kitakyushu, Japan 33.53N, 130.53E	Heat transmission	Wall : 1.7 W/m ² K Roof : 2.2 W/m ² K
Climate type	warm humid temperate climate with hot summers and no dry season	Albedo	Concrete Roof : 0.4 Concrete Wall : 0.4
Simulation day	7th August, 2012 from 6am - 7pm	Temperature	Outdoor start at 6am : 301.15K (28C)
Spatial resolution	1 m horizontally, 2 m vertically		Indoor start at 6am : 300.15K (27C)
Wind Speed	Start at 1.5 m		
Wind direction	60° NE		
Air humidity	79%		

4. Results - Microclimate at street level

4.1. Air Temperature

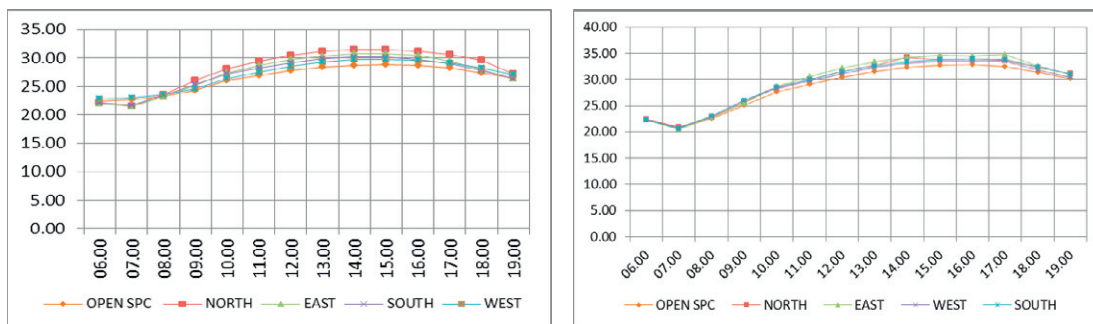


Fig. 4. (a) Air temperature for Building Group 1 (G1) ; (b) Air temperature for Building Group 2 (G2)

The diurnal of alteration of the air temperatures between G1 and G2 are shown on Fig.4. Air temperatures for both building groups reach the highest at North-side and the lowest temperatures are at the open-space points. The highest temperature for G1 was reached on 31.6°C at 3pm and G2 reached on 35.64 °C at 3pm. From this comparison, groups of buildings with heights of 50 m (G1) provide temperature lower than the group with building heights of 25m (G2).

4.2. Wind Speed

The maximum wind speed is noted at the north side for G1 and G2 at the west side. The configurations both of G1 and G2 at open space are categorized as light air (0.3-1.5 m/s) by Beaufort scale. The variety of group configurations on G1 delivers a range of speeds between 0.2 to 1.27 m/s for different orientations; meanwhile, for building on G2 which is dominated with NW – SE orientation, its open-space area was noted to deliver the lowest wind speed of 0.93 to 1.03 m/s. The wind speeds for G1 and G2 can be seen at Fig.5

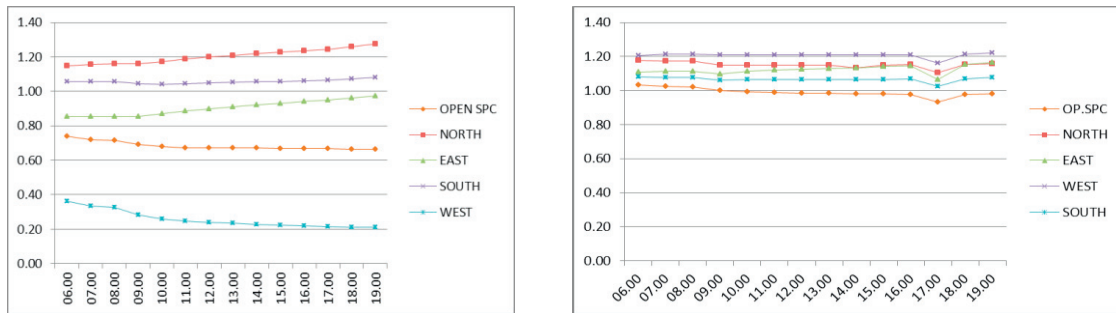


Fig. 5. (a) Wind Speed for Building Group 1 (G1) ; (b) Wind Speed for Building Group 2 (G2)

4.3. Mean Radiant Temperature

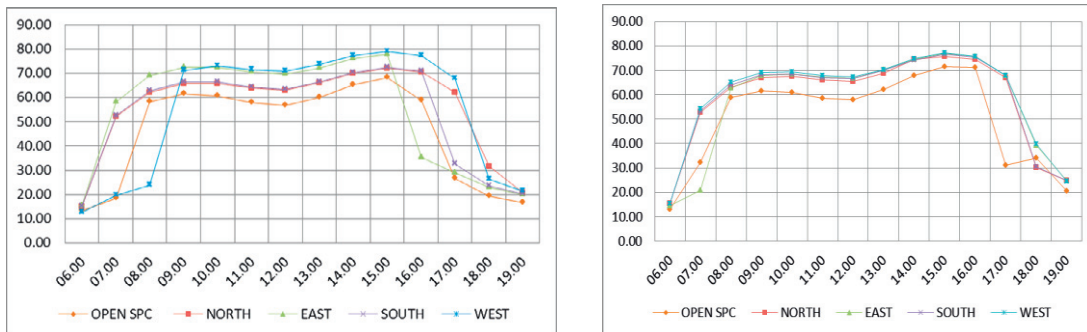


Fig. 6. (a) Mean Radiant Temperature for Building Group 1 (G1) ; (b) Mean Radiant Temperature for Building Group 2 (G2)

Fig.6 shows a good agreement with field study findings that wind speed in urban areas is influenced by the urban obstacles and their orientation. These two factors mean that radiant temperature and wind speed can be modified or changed by different height to width ratio or orientation [4].

5. Building Form and Layout Analysis

5.1. T_a and T_{mrt} for as a result of building configuration

The configuration of building groups which creates open space shows the differences between (a) Air Temperature (T_a) and (b) Mean Radiant Temperature (T_{mrt}) on one of the case studies. Fig. 7 shows that on 7th August, both the highest of T_a and T_{mrt} for G1 are reached at 3pm. The radiation fluxes expressed by T_{mrt} are very sensitive to geometrical properties. T_{mrt} reaches 68°C for the sunlit part of the open space and 64.9-75.4°C for the street and about 33.68-44.11 °C for the shaded area. In contrast, T_a for sunlit part of open space reaches 28.9-29.2 °C, 30.98-31.66 °C for street and 29.9-31.66 °C for shaded area.

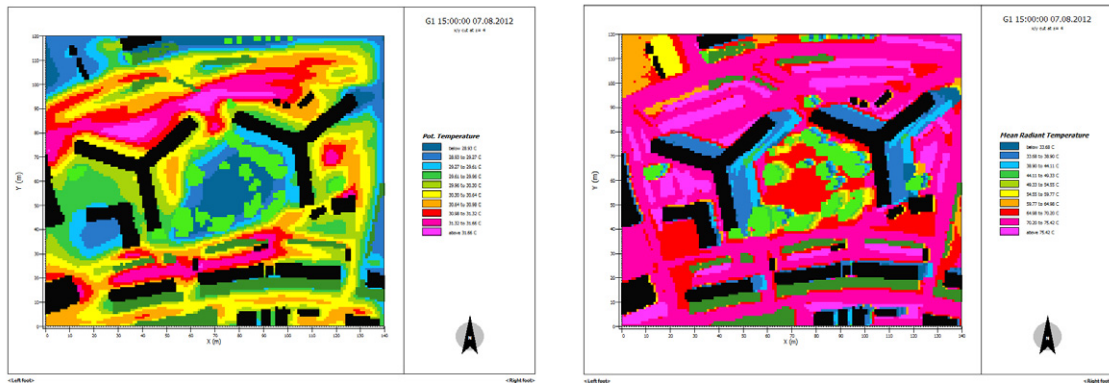


Fig. 7. (a) Ta at 15.00 for Building Group 1 (G1) ; (b) Tmrt at 15.00 for Building Group 1 (G1)

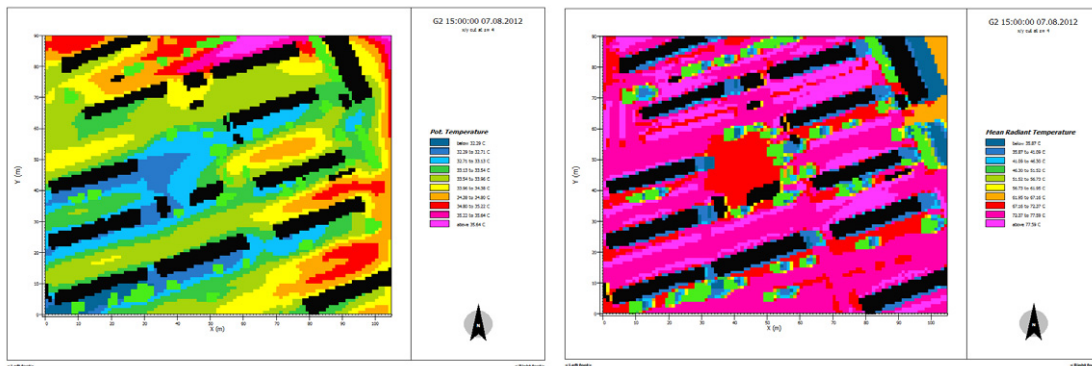


Fig. 8. (a) Ta at 15.00 for Building Group 2 (G2) ; (b) Tmrt at 15.00 for Building Group 2 (G2)

Fig. 8 shows that on 7th August, both the highest of Ta and Tmrt for G2 reach at 3pm. The radiation fluxes expressed by Tmrt are very sensitive to geometrical properties. Tmrt reach 71.8°C for the sunlit part of the open space, 72.37-77.59°C for the street and about 35.87-46.30°C for the shaded area. In contrast, Ta for sunlit part of open space reach 32.29-33.15 °C, 33.54-34.8 °C for street and 32.29-33.54 °C for shaded area.

5.2. H/W Ratio for N-S and E-W orientation

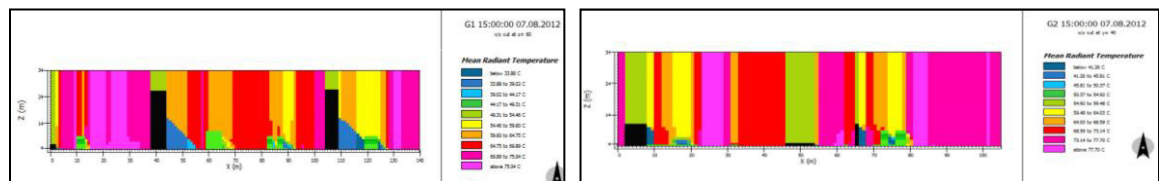


Fig. 9. (a) N-S orientation of G1 at 15.00 Tmrt x-z cut at y=60; (b) G2 15.00 Tmrt x-z cut at y=40

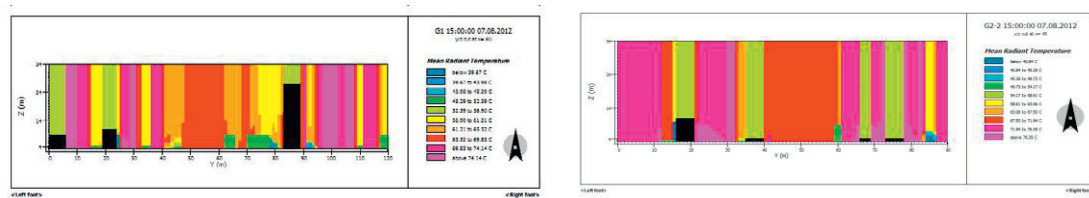


Fig. 10 (a) E-W orientation of G1 at 15.00 Tmrt y-z cut at x=80; (b) G2 15.00 Tmrt y-z cut at x=45

The section of simulation of Tmrt shows that both of G1 and G2 reach the lowest Tmrt at North-South orientation. Fig.9 shows G1 reaches the lowest Tmrt (blue area) at 33.88 °C – 44.17 °C in the range of 10m on open space between the buildings; meanwhile, G2 reaches the lowest Tmrt at 41.26 °C – 50.37 °C in the range of 2m on open space between the buildings.

Fig. 10 shows that G1 for E-S orientation reaches the lowest Tmrt at 39.67 °C – 48.29 °C in the range of 4m on open space between the buildings; meanwhile, G2 reaches the lowest Tmrt at 40.84 °C – 49.73 °C in the range of 3m on open space between the buildings.

From the section of x-z and y-z of both of orientations, it shows that G1 with building height = 50m delivers Tmrt lower than G2 with building height = 25m

5.3. Resume of Simulation

The resume of simulation for Ta and Tmrt for the comparison of two building groups which is shown at fig.11 is related to urban form and configuration between G1 and G2 for open space, street and shaded area. Both of Ta and Tmrt for G1 are lower than those of G2 on open space, street and shaded area.

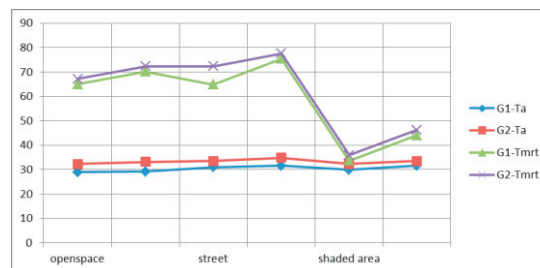


Fig. 11 simulation for Ta and Tmrt for the comparison of two building groups

6. Conclusion

The higher building with vegetation around open space provides lower temperature, higher speed of wind and it will influence the mean radiant temperature which can develop a better urban microclimate. North orientation is potential to reduce high temperature because of its wind direction. Providing active open space, such as park and playground with proper vegetations, also proves to deliver lowest air temperature and mean radiant temperature as well.

These simulations are part of an ongoing extensive study on the impacts of building form and layout to urban microclimate; another sample of building configuration will deliver more evidence to the importance of outdoor temperature, which significantly influences indoor temperature by setting the building by its height and distance between buildings and orientation.

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